View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Research Online

University of Wollongong
Research Online

Coal Operators' Conference
Faculty of Engineering and Information Sciences

2018

Mechanical Behaviours of Grout for Strata Reinforcement

Ali Mirzaghornanali
University of Southern Queensland

Peter Gregor
University of Southern Queensland

Hamed Alkandari

Naj Aziz
University of Wollongong

Kevin McDougall

Follow this and additional works at: https://ro.uow.edu.au/coal

Recommended Citation

Ali Mirzaghornanali, Peter Gregor, Hamed Alkandari, Naj Aziz, and Kevin McDougall, Mechanical Behaviours of Grout for Strata Reinforcement, in Naj Aziz and Bob Kininmonth (eds.), Proceedings of the 2018 Coal Operators' Conference, Mining Engineering, University of Wollongong, 18-20 February 2019
https://ro.uow.edu.au/coal/717

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

MECHANICAL BEHAVIOURS OF GROUT FOR STRATA REINFORCEMENT

Ali Mirzaghornanali[1], Peter Gregor[2], Hamed Alkandari, Naj Aziz and Kevin McDougall

ABSTRACT: Past studies on mechanical properties of grout were critically investigated and classified. Small scale and large scale samples were cast using cube and cylindrical moulds. Samples were left undisturbed to cure for various time intervals ranging from 1 to 21 days. Effects of sample scaling on the Uniaxial Compressive Strength (UCS) of Minova Stratabinder HS were studied, using a universal compression testing machine. In addition, rectangular samples were cast to investigate bending resistance of the grout product. Four point bending test was carried out on the samples with curing time ranging from 1 to 21 days. It was found that compression resistance of the grout increased with respect to curing time and initial studies on flexural strength showed that the bending resistance of grout reduced with prolonged curing times.

INTRODUCTION

Rock bolt systems were first introduced for use as mining ground supports during the late 1940's (Mark, 2017) in the form of mechanical anchoring. As a result, of the increasing popularity and widespread implementation of rock and cable bolts, numerous design variations were conceived in order to meet the explicit criteria. The development of resin and grout anchorage allowed for greater variation in rock bolt selection in order to meet specific operational requirements (Rajapakse 2008).

Cementitious grout has become a primary method of anchoring cable bolts, unlike ordinary rock bolts (Mirzaghorbanali, *et al*., 2016). However, due to the increased use of non-metallic rock-bolts for rib support, cementitious grout has become a popular method for the anchoring of ordinary rock bolts. Due to similar grout preparation and installation processes, rock bolts are prone to similar premature failure of grout to that of cable bolts due to erroneous installation practices. Correctly installed grouted supports can provide a safe, cost effective and long-term form of reinforcement for; wedge/flake stabilisation, arching, tieback, suspension and forepoling.

Previous studies in literature have focused on both the mechanical properties of grouts and resins *(Aziz, et al*., 2014; Mirzaghorbanali, *et al*., 2016) in addition to their encapsulation properties (Aziz, *et al*., 2016). Moreover, the studies have resulted in the determination of the mechanical properties of grouts and resins for use with both cable and rock bolts as well as establishing a general practice standard.

The study conducted by Aziz, *et al*., (2014) analysed the effects of varying resin sample properties in accordance with the various standards (*ASTM C-759* 1991; *South African Standard (SANS1534)* 2004; *BS 7861* 2009) to determine the effects of:

- Sample shape,
- Sample size,
- Height to width or diameter ratio,
- Resin type,
- Resin age and
- Curing time.

Samples were subjected to the testing procedures in accordance with the various standards of testing to determine:

- Uniaxial Compressive strength (UCS),

[1] *Ali Mirzaghornanali. Email: Ali.Mirzaghorbanali@USQ.edu.au: Tel: +61 7 46 631 2919*
[2] *Peter Gregor, Email: Peter.Gregor@usq.edu.au*

- Modulus of Elasticity,
- Shear Strength and
- Creep/rheological properties.

Additionally, Hagan, *et al*., (2015) through the Australian Coal Association Research Scheme (ACARP) organisation investigated the effects of water to grout ratio on the UCS of both cylindrical and cube samples. The study identified a declining relationship in UCS strength with the increase of water concentrations. Moreover, when compared to cylindrical samples cube samples achieved higher UCS values.

Furthermore the study conducted by Mirzaghorbanali, *et a*l., (2016) investigated the effects of curing time on the mechanical properties of grouts Jennmar BU 100 and Orica Stratabinder. Cube samples were prepared at tested at 1, 7, 14 and 28 days curing. The study concluded that:

- The compressive strength of grout increasing with curing time, and
- Both products are suitable for use in strata reinforcement.

SAMPLE PREPARATION AND EXPERIMENTAL PROCEDURE

The grout product Orica Stratabinder HS was selected to prepare the samples. The uniaxial compressive strength (UCS) samples were cast using two moulds; the small-scale 70mm cube mould and the large-scale 100 mm x 200 mm cylindrical mould. The flexural samples were cast using 350 mm x 100 mm x 50 mm prismatic moulds. Shown in Figure 1 is the mixing process for grout and the casting moulds. Samples were cast using a mixing ratio of 7 litres of water/bag and the application of slight vibration to remove trapped air. All samples were prepared at curing times of 1, 7, 14 and 21 days.

EXPERIMENTAL RESULTS AND DISCUSSION

Uniaxial Compressive Strength (UCS)

To conduct the UCS tests samples were prepared at 1, 7, 14 and 21 days curing times for each small and large-scale test as shown in Figure 2. Some tests were repeated to ensure accuracy of the collected data and the best four tests per sample type were presented.

The UCS values for large scale and small-scale samples at various curing times are presented in Figure 3. It is observed that the UCS values of the small-scale samples are higher than those of the large-scale ones for various curing times. The difference between the UCS of the large scale and small-scale samples is more pronounced for 7 days curing times where the UCS of the small scale is 68 MPa whereas the large-scale is 28 MPa. Figure 3 also indicates a delay in the strengthening process of the large-scale samples where the observed UCS difference between 1 day and 7 days for the large-scale test is just 2.1 MPa as opposed to 23.9 MPa for the small-scale test. The observed failure mechanisms were typical to that of those grout samples and presented in two stages. Failure can be identified by the formation of micro-cracks, which then leads to the second stage involving crack propagation.

The obtained UCS values show an increase in strength over the 21 day curing period for both small and large-scale samples, 44.1 MPa to 84.1 MPa and 25.9 MPa to 71.7 MPa respectively as shown in Figure 3.

The results of the two sample sizes were compared to determine a scale ratio. The Scale ratio is defined as the UCS value of small-scale samples to large-scale samples, and as shown in Figure 4 it varies from 1.1 to 2.4 depending on curing time.

Figure 1: [left] Grout preparation [right] a view of large scale UCS and flexural moulds

Figure 2: Prepared Samples [left] large scale cylinder UCS [right] small scale cube UCS

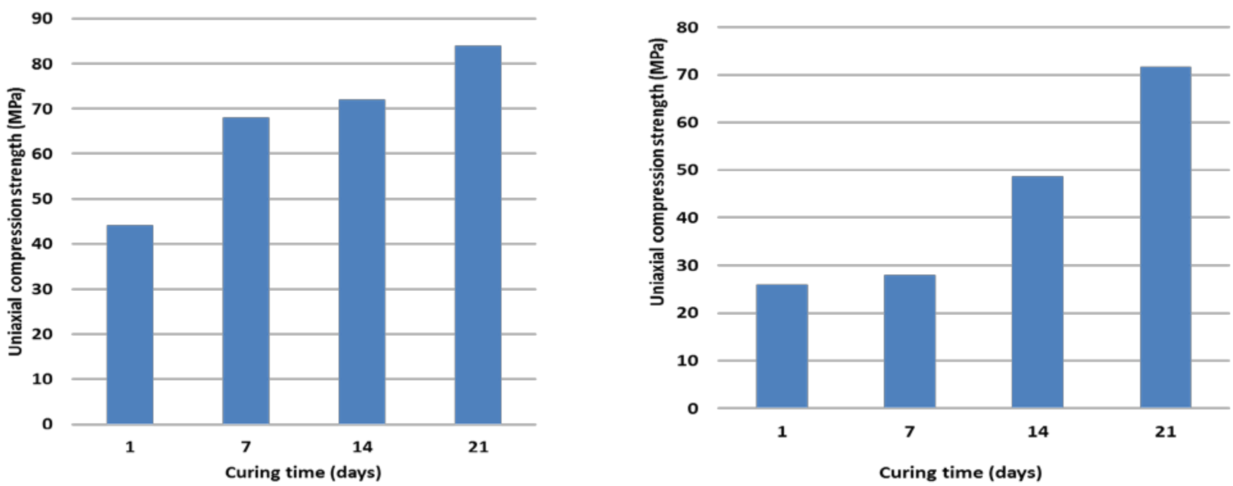

Figure 3: UCS values at 1 to 21 curing days [left] small scale samples [right] large scale samples

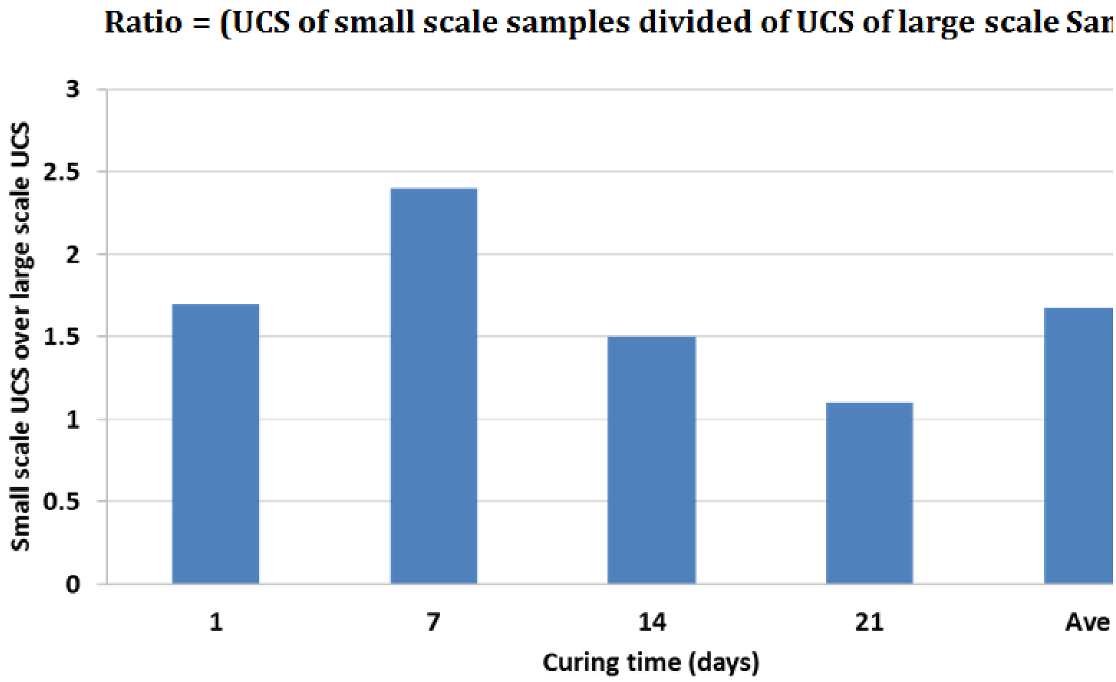

Figure 4: The scale ratio for different curing times

Bending Resistance

Three four-point bending tests were carried out on prepared samples at 1, 7 and 14 days curing time. Some tests were repeated to ensure accuracy of the collected data. Figure 5 [left] shows the 1, 7 and 14 days prepared samples using Stratabinder grout and [middle] and [right] present the testing process and sample failure respectively.

Shown in Figure 5 are the four point bending failure loads at various curing times. Unlike the UCS tests, the bending strength of grout decreased over time with initial values of 1.9 kN reducing to 0.5 kN throughout the curing period. The failure mechanism presented in the bending tests was identical to that of the UCS tests.

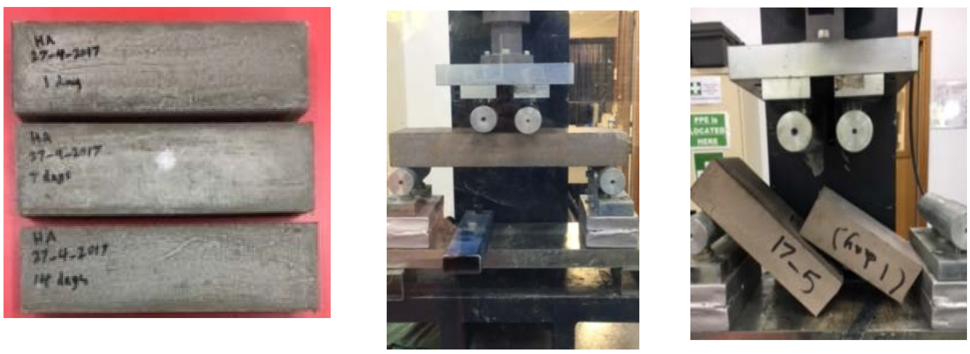

Figure 5: Four-point bending sample [left] prepared bending samples [middle] four-point bending test setup [right] sample failure

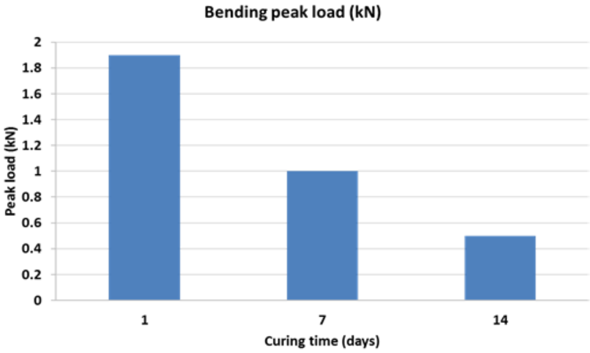

Figure 6: Bending strength of Stratabinder at various curing times

CONCLUSIONS

The experimental study found that the UCS of both small and large-scale grout samples increased with respect to curing time. For the seven-day curing times however, small-scale samples presented with better performance with significant strength improvement to that of the previous test when compared to the large-scale tests. Experiments indicated an increased overall response to curing times in the small-scale samples to that of the large-scale. It is noted that the result of large scale testing is more preferred for the sake of design in comparison to that of small scale testing. However, the small scale testing is the preferred method of testing due to its simplicity. Therefore the determined scale ration (1.7) allows for the results of small-scale tests to be easily converted to the large-scale scenarios for further Geotechnical implementation such as underground or slope stability analysis. Results of bending tests contradict the initial expectation based on which the peak-bending load should increase with an increase in the curing time. Therefore, it is suggested to carry out further investigation to study in detail the influence of curing time on bending properties of grout samples.

REFERENCES

American Standards for testing materials (ASTM C-759), 1991, *Standard test method for compressive strength of chemical –resistant mortar, grouts, monolithic surfacing and polymer concretes*, ASTM, Philadelphia PA.

Aziz, N, Craig, P, Mirzaghorbanali, A, Nemcik, J, 2016. *Factors influencing the quality of encapsulation in rock bolting.* Rock Mechanics and Rock Engineering, vol. 49, no. 8, pp3189-203.

Aziz, N, Nemcik, J, Mirzaghorbanali, A, Foldi, S, Joyce, D, Moslemi, A, Ghojavand, H, Ma, S, Li, X, Rasekh, H, 2014. *Suggested methods for the preparation and testing of various properties of resins and grouts*, in 14th Coal Operators' Conference: Proceedings of the 14th Coal Operators' Conference, N Aziz (ed.), University of Wollongong, Wollongong, pp163-76.

British Standards (BS 7861), 2009, *Strata reinforcement support system components used in coal mines - Part 1: Specification for rockbolting and Part 2: Specification for Flexible systems for roof reinforcement*. 1 and 2, BSI.

Hagan, P, and Chen, J, 2015. *Optimising the selection of fully grouted cable bolts in varying geotechnical environments,* Australian Coal Association Research Program (ACARP C22010).

Mark, C, 2017. *Design of roof bolt systems,* US Department of Labor, Pittsburgh Research Laboratory, Pittsburgh, PA.

Mirzaghorbanali, A, Aziz, N, Ye, W, Nemcik, J, 2016. *Mechanical properties of grouts at various curing times*, in Coal Operators' Conference Proceedings of the Coal Operators' Conference N Aziz (ed.), University of Wollongong Wollongong, pp84-90.

Rajapakse, R, 2008 25 - *Soil Anchors and 26 - Tunnel Design*, in Geotechnical Engineering Calculations and Rules of Thumb, Butterworth-Heinemann, Burlington, pp321-41.

South African Standard (SANS1534), 2004. *Resin capsules for use with tendon based support systems*, Standards South Africa.